REPORT

ON

W. BELL DAWSON, C.E.

ON

SURVEY

OF

TIDES AND CURRENTS IN CANADIAN WATERS

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OTTAWA, 13th January, 1894.

W. P. ANDERSON, Esq., C.E.,
Chief Engineer, Department of Marine and Fisheries.

SIR,—I have the honour to submit the following report with regard to the Survey of Tides and Currents in Canadian waters.

At the present stage which this work has reached, it may be well to begin by reviewing concisely the representations that have been made during the past years in bringing this matter before the notice of the Government, and the steps that have already been taken.

As long ago as the meeting of the British Association held in Montreal in 1884, the importance of publishing tide tables for Canadian waters, and the necessity of establishing stations for tidal observations was discussed. The Association adopted a resolution drawing the attention of the Government of the Dominion to the matter, and also appointed a committee to collect information and make representations to the Government regarding it. The committee consisted of Dr. A. Johnson, chairman; Professor J. G. MacGregor, of Halifax; J. B. Cherriman, of Toronto; H. T. Bovey, of Montreal; and C. Carpmael, Director of the Meteorological Service. The Montreal Board of Trade were at the same time considering the question independently, and they concurred addressing a strong memorial on the subject to the Dominion Government. Ship owners and masters of ships were also practically unanimous as to the pressing need for knowledge on the subject of the tides and currents.

During the following sessions of Parliament, petitions and representations were made through the then Minister of Marine. In reply, this Minister stated that owing to the outlay on the Georgian Bay Survey, and the expedition to Hudson's Bay during the summer of 1885, the Government did not propose to take action in the matter of tidal observations at that time.

In January, 1886, a large deputation representing the British Association, and the Royal Society of Canada, with representatives of the Board of Trade of Montreal, waited on the new Minister of Marine (the Hon. G. E. Foster), and also on the Premier, Sir John Macdonald. The matter was favourably received and fully discussed; and in the official answer it was stated that while the Government was fully sensible of the importance of establishing stations for continuous tidal observations in Canadian waters, it did not propose at that time, owing to the large expenditure on surveys and explorations in other directions, to undertake the additional expense

involved; it was, however, fully alive to the importance of the matter, and hoped in the near future to be able to carry out a work so necessary and useful to the commercial interests of the country.

On the return of the Hudson's Bay expedition, a new source of expenditure arose; as the Government undertook to pay half the cost of a re-survey, by the British Admiralty, of part of the Lower St. Lawrence. In the summer of 1887, however, Lieut. Gordon, R.N., who had been in command of the expedition to Hudson's Bay, was authorized to make some test observations at a few points by means of the tide-staff with a view to ascertaining how far the accepted tidal establishments were to be relied upon. These observations were taken at Georgetown, P.E.I., at Louisburg, C.B., at Pictou, N.S., and at Port Hawkesbury in the Strait of Canso. In his report on this work, Lieut. Gordon explains that the object of these observations was to show to what extent the means now in the hands of navigators for the prediction of the tides on the coasts of Canada were in error; and he finds the results to show, as far as they go, that the means of prediction are very imperfect, and in some cases (such as the Strait of Canso) actually misleading. While admitting that these observations were too few in number and too rough in their nature to found any conclusions on, Lieut. Gordon considers that the results certainly strengthen the opinion that the whole question of the determination of tidal constants should be taken up in Canada, and a number of stations established for taking tidal observations; as these would be of the greatest practical value to seamen. He further points out the special value which this work will have when completed, as it will enable an intelligent ship master not only to see at what time the tide will be high or low, but also to see at once how the tidal current is setting his ship, when once the currents are charted for the waters of the Gulf.

As Staff Commander Maxwell, R.N., was at that time carrying on the re-survey in the Lower St. Lawrence, his attention was called to the memorial of the committee of the British Association, and he was asked by the department to state the nature and extent of such tidal observations as he was making. His reply is to the effect that he was doing what he could to observe the tides and currents with the means at his disposal; but that they were confessedly imperfect, and were confined to a limited area, and did not necessarily establish any comparison with any other portion of the river. To do this work in a comprehensive way, he considers the most trustworthy method to be the establishment of self-registering tide gauges at various points in the River and Gulf of St. Lawrence; with one or more vessels from which to observe day by day the condition of the tidal streams under varying states of wind and weather.

Up to the time of the accession to office of Sir C. Hibbert Tupper, K.C.M.G., as Minister of Marine in the autumn of 1888, no steps had been taken to carry out the work in accordance with the representations made. As Lieut. Gordon had spent the summer of 1888 in navigating the waters of the Gulf of St. Lawrence, he addressed a report to the Minister based upon the further information he there gained, after carefully watching the effects of currents on his ship's course. In this report he expresses the conviction that until we have an exhaustive examination of the whole system of tidal movements, carried out on similar plans to those which have been made on the United States' coasts, and on the coasts of Great Britain, we shall always be subject to an annual amount of maritime loss due to the lack of information in regard to tidal currents. He also points out that in the 18 years from 1870 to 1887, the aggregate loss was a little over 50 million dollars, or an average of $2,782,000 per annum; and in the same period the loss of life has been 4,308 lives. A certain proportion of this loss of life and property is certainly due to imperfect knowledge of the currents; and if the number of narrow escapes of vessels from disaster or wreck were known, it would add a powerful argument in favour of proceeding with the work forthwith. He also adds that if we could only get a record of the narrow escapes, the delays, and the errors of position discovered when a fog clears away, no further argument would be required; but captains of vessels as a rule dislike to admit that they have been out of position; and dangers escaped are only remembered in a practical sense by giving the ship a little more offing the

next voyage, when, if the weather is thick, it may be found that the ship is as far to the north as she was on the previous trip to the south. It is the more difficult under these circumstances to collect evidence on the subject. He is himself convinced, however, of the extreme desirability, if not the absolute necessity of proceeding with this work as soon as possible.

During the summer season of 1889 little was done of a practical character, beyond exploratory trips made by Lieut. Gordon and Mr. Carpmael, with a view to ascertaining the best points for the establishment of tide gauges.

At the conclusion of the re-surveys in the Lower St. Lawrence with this season, the expenses of which were being shared by the Canadian Government and the British Admiralty, the time was regarded as opportune to make further representations as to the pressing need for information about our tides and currents. Accordingly, in December, 1889, a petition was addressed to the Minister of Marine and Fisheries which was drawn up by the Committee of the British Association, and the Royal Society of Canada, and was signed by 393 masters and officers of vessels, to the following effect:—

"We, the undersigned masters and officers of vessels engaged in the navigation of the Gulf of St. Lawrence and of the waters on the Atlantic coast of the Dominion of Canada and of Newfoundland, desire earnestly and respectfully to petition the Government and Parliament of Canada, that they would promptly take such steps as they may deem advisable to obtain as thorough a knowledge as possible of the currents in these waters, whether due to the tides or to any other cause, and to distribute amongst mariners the information obtained. We believe that the serious loss of life and property due to shipwrecks attributable to unknown currents during fogs or hazy weather may thus be greatly diminished. In such weather these currents are a cause of great anxiety and danger."

A further memorial was presented to the Minister by the Shipping Interest of Montreal, bearing the representative signatures of Messrs. H. and A. Allan, David Torrance & Co., H. E. Murray, Anderson McKenzie & Co., and F. W. Henshaw. This memorial points out the special deficiency in Canada of such information to mariners as is supplied by the Imperial Government in the British Tide Tables; which show not only the change in the depth of water due to rise and fall of the tide, but also supply very full information about the currents in the waters surrounding the British Islands, whether due to the action of the tides, or influenced by atmospheric causes. The annual wreck list is referred to, as showing the urgent need of similar information for Canadian waters; and as far as ascertained, ship-masters were unanimous in their anxious desire for information on the subject. The need of taking immediate action in the matter is urged, as the necessary observations will occupy some years, and every year before their completion will show its list of preventable wrecks.

This memorial was also heartily endorsed by the President of the Quebec Board of Trade. It was referred to Captain W. H. Smith, R.N.R., Chairman of the Board of Examiners of Masters and Mates, who has had thirty years' experience in the Atlantic service; and in reply he concurs in recommending that self-registering tide gauges be placed at all the prominent ports, and observations taken by competent persons.

About the same time a further communication was received from Dr. Johnson, on behalf of the Committee of the British Association, which reviews the representations already made by them. Amongst other reasons adduced, the rule of the Imperial Board of Trade is referred to. This requires all masters of ships to obtain a certificate of competency, and for this purpose to pass an examination; which examination, in the case of masters desiring a certificate for the coasting trade, includes a knowledge of the tides and tidal currents. The information enabling them to pass this examination is found in the tide tables published by the Admiralty. This is cited to show the need of obtaining data for Canadian waters on which similar information could be based. The recent re-survey of part of the Lower St. Lawrence under Staff Commander Maxwell, is also referred to; and his endeavour as far as time permitted him, to investigate the tides and currents in the part of the river in

which he was at work; although he acknowledges his means to be limited and insufficient to establish comparisons with other points. The opinion of Captain Lecky, R.N.R., is also quoted from his work on "Practical Navigation." This work has received the approbation of the naval authorities of Great Britain and of the United States, and is supplied to the fleets of both these countries. In it he gives a list of 16 books which he says "may be considered absolutely essential to safe navigation in the present day, when the question of speed enters so largely into the calculation." His list includes the Admiralty "Tide Tables" and Galbraith and Haughton's "Manual of the Tides and Tidal Currents" for the waters surrounding the British Islands.

COMMENCEMENT OF THE WORK.

In the following season of 1890 a practical commencement was made. It was proposed to make some further preliminary observations; to purchase a few tide gauges; and also to make available, as far as might be possible, some old tidal records for the years 1860 and 1861, which were discovered in the archives of the Hydrographic Office, formerly at Halifax. For these purposes a sum of $2,000 was made available; and out of this amount a sum of $1,654.96 was expended on the above objects.

The proposed observations were made by Lieut. Gordon at two points on the Atlantic coast of Nova Scotia; the object in view being to check the accuracy of the tidal differences between Halifax and other points along the coast, in order to make Halifax if possible a "port of reference" for the whole eastern coast of Nova Scotia from Scatarie Island to Cape Sable. This was the most important thing to do first, because of the hope that the records above referred to might prove a sufficient basis from which to compute tide tables for Halifax, which might serve in the meantime until a longer series of observations could be obtained. A further object in these preliminary observations, was to ascertain by the use of different appliances and methods, those which promised to give the best and most economical results. The details of this work and the descriptions of the appliances used are given in Appendix No. 16 to 23rd Annual Report, Department of Marine and Fisheries for 1890.

To ascertain the best form of tide gauge to employ, the most careful and exhaustive inquiries were made by the Minister, aided by the advice of Mr. Carpmael, Director of the Meteorological Service. The difficulties in the case were exceptional as at most points any ordinary apparatus is liable to freeze up in winter, and so to interrupt the record; and further, on grounds of economy, it was considered impossible to employ skilled observers for this special work, at the requisite number of stations.

The Tides themselves on the coasts of Canada, vary so much in their amount (from a height of four or five feet in the open Atlantic, to twelve and eighteen in the St. Lawrence River, and thirty feet and over in the Bay of Fundy) that a relatively large number of stations are required in order to follow their movements in any satisfactory way. In these circumstances a self-recording tide gauge, which will do the work of making the record of the tide day and night, with the least amount of supervision, is the most suitable and economical to use. To prevent freezing, and so to secure the record in winter as well as in summer, Mr. Carpmael made special inquiries and experiments which are referred to in his report of December, 1890. (Appendix No. 16 to Annual Report, Department of Marine, 1890.) In making choice of the best form of tide gauge, Professor G. H. Darwin, of Cambridge, the most eminent specialist on tidal questions, was consulted. He kindly gave his advice in the matter; with a view also to the reduction of the observations, and calculation of tide tables from them. The gauge finally decided upon was the one devised by Sir William Thompson, and three of these were accordingly purchased to begin with.

The records of the Halifax tides above mentioned were submitted to Mr. Edward Roberts, of the Nautical Almanac Office. Although there were breaks and imperfections in the record, he devised a special method of double computation by which these could be successfully overcome; and he was therefore able to report

favourably upon them, and to recommend that tide tables should be computed from them. In making the calculations of these tides an ingenious and expensive computing machine was placed at the service of this department for a merely nominal fee. This machine was devised to facilitate the extensive tidal calculations made by the Government of India. It this way tide tables were prepared for Halifax, first issued for the year 1891, and since published annually by this department. These tables also contain tidal differences which make them available for all the important harbours on the eastern or Atlantic coast of Nova Scotia.

TIDE GAUGES, AND TIDAL STATIONS ESTABLISHED.

In order to decide upon the most suitable points at which to erect the tide gauges, the advice of Mr. T. C. Mendenhall, superintendent of the United States Coast Survey, was asked, which he kindly gave, and Mr. Carpmael also visited personally a number of localities along the Lower St. Lawrence and in the Gulf, at such times during the following season as his other duties would permit. At this time also the ill health and subsequent death of Lieut. Gordon, removed him from further participation in the work, and left it entirely on Mr. Carpmael's hands.

The points considered most suitable for the erection of the first gauges were Father Point, the south-west point of Anticosti Island, and the harbour of St. John, N.B.; and the sites which have been chosen for three additional gauges since purchased, were the Magdalen Islands, St. Paul Island, C.B., and the harbour of Quebec. For the purchase and erection of these gauges, an appropriation of $10,000 was placed at the disposal of this department in each of the fiscal years of 1891-1892, 1892-1893, and 1893-1894, but the actual expenditure in the first two of these fiscal years was little over one-fourth of the appropriation voted.

The tide gauge itself consists essentially of a cylinder in an upright position, which is made up to revolve by clock-work, once in 24 hours, and around this cylinder, a sheet of graduated paper is placed. The tide, as it rises and falls, causes a float to move up and down in a vertical pipe, which communicates by a suitable opening with the sea. This float is connected by a fine wire with the wheels and gearing of the gauge, in such a way as to cause a pencil to move up and down along the cylinder, in exact accordance with the movements of the tide, but with a much reduced range. The combined effect of the motion of the pencil and the rotation of the cylinder, is to trace on the paper an undulating curve which represents the tidal wave itself on a reduced scale. From this curve the height of the tide, the times of high and low water, and all the other elements required can be measured. Also as high water is an hour later each day, the curves showing the tides on successive days will fall behind each other, and the gauge may therefore be allowed to go on making its record for a week on the same sheet without confusion of the curves. Alongside of this recording gauge a "sight-gauge" is placed to check the record on the other, and also to furnish a datum from which to measure the height of the tide. For this purpose there is a second vertical pipe, and a float with a staff upon it, which moves up and down with the tide itself. If the range of the tide is great, a steel tape passing over a pulley is used instead of the upright staff. The readings of this staff or tape need only be taken twice a day at convenient hours, and the corresponding points marked on the continuous record.

In placing such an appliance in position to record the tide, it is evidently necessary to secure the whole range of the tide within the vertical pipes. On ordinary beaches this can only be done by setting the whole appliance out in the water beyond the line of low tide; or else by placing it on shore and leading the tide to it by a trench or piping. It is this that occasions the chief expense in erecting the gauges in positions where there is no wharf already available, against which the gauge can be placed. The vertical pipes require to be surrounded by an open space in which heating is supplied in winter to prevent freezing, and their connection with the sea is made by means of a rose of small holes, so arranged as to reduce or efface the motion of waves within the vertical pipes.

In establishing the tide stations above mentioned, it was sometimes necessary in order to obtain the whole rise and fall of the tide, to contruct a small crib of timber, and on this a small tide-house was placed to protect the instruments from the weather. These stations were erected under the immediate supervision of Captain Douglas, R.N.R., and their establishment often called for much judgment in meeting with practical difficulties which arose, and in taking advantage of local features to obtain sufficient shelter, in order to provide against their destruction by the ice, and the severe gales of the winter season. It will be unnecessary to describe the stations in detail beyond giving the following list of them, with the observers in charge, and the time during which they have been in operation to date.

TIDE GAUGE STATIONS ESTABLISHED UP TO DECEMBER, 1893.

St. John, N.B.—Gauge placed against wharf in harbour. D. L. Hutchinson, meteorological observer, in charge. In operation since December, 1892.

South-west Point, Anticosti.—Crib erected for gauge. H. Pope, lighthouse-keeper, in charge. Observations commenced July, 1893.

St. Paul Island, C.B.—Gauge on a crib built into an opening between rock cliffs. John Campbell, lighthouse-keeper, in charge. Observations commenced September, 1893.

Magdalen Islands.—At Grindstone, on east side of the islands. Gauge in a well in a timber breakwater for better protection. A. Le Bourdais, local superintendent of telegraphs, in charge. Observations commenced October, 1893.

Quebec.—Gauge placed at the Lévis Dry Dock. U. Valiquet, engineer of Dry Dock, in charge. Observations commenced November, 1893.

Father Point.—(Unfinished). Gauge to be placed in a well sunk on shore, and tide to be led to it by a trench and piping.

TIDES.

In the interests of shipping, the investigation of the tides has in general, three aspects: (1) The times of high and low water at the principal harbours of the country, and the range of the tide. (2) The times of high and low water at the smaller ports along the coasts, and the depth of water on shoals and bars at their entrances; in which the coasting vessels are especially interested. (3) The effects of the tides in producing currents. In this last respect the Lower St. Lawrence, the Bay of Fundy, and the inlets on our Pacific coast, are amongst the most noteworthy examples to be found anywhere. As regards high and low water, the aggregate interests of the coasting trade are probably as great as those of our few principal harbours,

In the St. Lawrence River itself above Quebec the tides have been observed for some time in connection with the work of improving the navigable channel of the river, carried out under the direction of Mr. Kennedy, Chief Engineer to the Harbour Commission of Montreal. Tide tables are now published by him for the use of the river pilots; and a signal station has been established to indicate the depth of water in the new channel. A detail account of these tides is also given by Mr. R. Steckle, C.E., of the Public Works Department; which is based upon observations taken while carrying out his system of levelling operations. The results are given and fully illustrated in his Report of December, 1891, addressed to Mr. L. Coste, Chief Engineer of Public Works.

In the river below Quebec, throughout the Gulf St. Lawrence and on the Atlantic Coast, the tidal information which he possess is still based on Admiral Bayfield's survey of nearly 60 years ago; and these data, as the Hon. G. E. Foster recognized while Minister of Marine, are not sufficiently accurate for the present time.

To obtain the required information, tidal stations must be established at commanding points, in order to follow the general course of the tides; and from these the local differences for the smaller ports can afterwards be determined. In the choice of the main stations, the chief difficulties is that the large harbours are often

the least suitable to use as stations from which to determine the tidal differences of other points along the coast. The reason for this is, that many harbours such as Quebec, St. John, N. B., and New York, are at the mouths of tidal rivers; and this has the effect of complicating the times of the tide with local conditions. To avoid this difficulty, Sandy Hook has been chosen instead of New York harbour, as a point of reference for other places along the Atlantic coast. At Quebec and St. John, the same local difficulties occur; and although it is necessary to observe the tides at these harbours on account of their own importance, it is doubtful whether St. John will answer satisfactorily as a port of reference for the Bay of Fundy. On this account it is advisable to establish an additional tide gauge as soon as possible at Yarmouth, which is the best available point. It is free from local influences, and the tides have a more medium range than at St. John, making results more reliable, and it best commands the entrance to the Bay of Fundy, as the tides enter the Bay from the southward. For the Atlantic coast of Nova Scotia, Halifax is undoubtedly the locality to select, as it has the advantage of combining both the objects referred to. It is a question however, whether it would be best to place the gauge in the harbour of Halifax, where the influence of the accumulated tide in Bedford Basin may have an appreciable effect. It may be found on examination that a point outside the harbour, such as Chebucto Head, may give better results for the actual tide of the Atlantic.

In recommending the establishment of a tidal gauge at Halifax, it may be well to explain that to obtain a satisfactory basis for tide tables at so important a point the observations should be continued for a period of 19 years. This is the period of revolution of the moon's nodes, and the period in which eclipses recur successively in the same order. Although there is a recurrence in each year of unusually high tides at the equinoxes in the spring and autumn, due to the combined influence of the sun and moon at those seasons, yet the declination of the moon is different at each succeeding equinox until the period of 19 years has elapsed. At the end of that time the sun and moon are again in positions with respect to the earth which are practically identical with those which they had at first; and the whole of the associated phenomena, including the tides, recommence again in the same sequence. This is therefore the shortest available lunar cycle for the correct computation of tides at any standard point.

As the Gulf of St. Lawrence forms a large area which is nearly land-locked, it is of the first importance to obtain complete information regarding the tides and currents at the two main entrances which connect it with the ocean. The northern entrance by the Strait of Belle Isle is only about 10 miles wide and 40 fathoms deep, while the other opening between Cape Breton and Newfoundland, known on the charts as Cabot Strait, has a width of 60 miles and a depth over the greater part of this extent of about 250 fathoms. In comparison with these the Strait of Canso need not be taken into account in its relation to the tides and currents of the Gulf as a whole; but with regard to these two main entrances themselves, it must not be taken for granted that their influence depends solely upon their relative dimensions. Judging by the movement of icebergs in the Straits of Belle Isle, the general opinion is that a large amount of cold water finds its way through it into the Gulf. This may be in reality a branch of the Arctic Current on its way south from Baffin's Bay. Although this entrance to the Gulf may seem unimportant as compared to the other, it should be remembered that a current of even half a mile an hour through this Strait would admit to the Gulf a volume of cold water more than 20 times greater than the volume discharged by the river St. Lawrence.

As regard tide however, there is little doubt that the amount entering the Gulf by the Strait of Belle Isle is relatively very small; but owing to the nature of tidal undulations, it is quite possible that its effects may be felt further than at first sight would seem likely. In addition to this, the tide is sure to have a direct influence on the movement of the current in the Strait. It is therefore necessary to establish a tide-gauge there as soon as possible. The best position will probably be at Forteau Bay, where there is a wharf and good shelter. This bay is also at the narrowest part of the Strait, where the currents can best be observed.

The main tide found in the Gulf undoubtedly enters by Cabot Strait (between Cape Breton and Newfoundland) from the general tidal wave in the Atlantic, which advances from the south-east. It is a remarkable fact that the tidal wave which enters here, does not lose itself is the great expanse of the Gulf area, but is again found with a range even greater than before in the passage between Gaspé and Anticosti, and from there continues its course, with ever increasing height, up the St. Lawrence to Quebec. This is well illustrated by the curves already recorded by the tide-gauges. The progress of the tidal wave in this leading direction, must be largely due to the existence of a deep channel, which crosses the whole extent of the Gulf from Cabot Strait to the passage referred to, between Gaspé and Anticosti; and thence extends up the St. Lawrence nearly to the Saguenay. This channel thus extends for a distance of 500 miles, with an average width of 35 miles, and a continuous depth of over 150 fathoms. It is this channel which forms an avenue of least assistance for the progress of the tidal wave.

This will explain in general the reasons for the positions chosen for the tide gauges. It was evident that observations at some point in Cabot Strait would furnish a key to the situation; but the rocky cliffs on both sides at Cape North, and Cape Ray, and the rocky character and exposed situation of St. Paul Island, made it appear impracticable to place a tide-gauge there. In locating the gauge on the Magdalen Islands, however, although it was placed on their eastern side, it soon became apparent that the tidal wave had already lost its full range in the expanse of the Gulf. A careful examination was therefore made to find if possible a position on St. Paul Island sufficiently sheltered to protect a gauge from destruction. The sheltered site at which the gauge now stands, was eventually discovered; and observations in Cabot Strait itself are thus secured.

On the main line of the progress of the tidal wave from St. Paul Island to Quebec, a distance of 650 miles, the intermediate tide stations which have been selected as most suitable are the South-west Point of Anticosti Island, and Father Point. These two points have the following important advantages: They are near to the edge of the main channel above described, which traverses the Gulf; and they are similarly situated with regard to it, as they are both within six or eight miles of the 100-fathom line; they are both situated on the open coast, where they are unaffected by such local conditions as might exist in a bay or inlet. On these grounds they are admirably adapted to follow the progress of the tide and serve as reference stations. The only position that can claim superiority to Father Point as commanding the mouth of the St. Lawrence, is Point des Monts on the north shore; as this stands more truly at the dividing line between the river and the Gulf. Against this, however, Father Point has the practical advantage of being the Pilot Station, where direct information regarding tides and currents is of the first importance and can be made directly available.

In this chain of tidal stations an important region is still omitted. The line of the main channel across the Gulf from Cabot Strait to Gaspé, is very direct with only a slight bend to the north-east in passing the Magdalen Islands. This main channel thus forms the deep water edge of the large semi-circular bay of comparatively shallow water, which is bounded by the wide sweep of coast from Gaspé along New Brunswick to Cape Breton; and in which Prince Edward Island lies. The depth of water throughout this bay averages only about thirty fathoms; and the tidal wave has to pass over an extent of about 200 miles of this shallow water to reach its shores. It is therefore most important to establish at least one tide station somewhere near the centre of the sweep of coast which bounds it. The position I would recommend would be in the vicinity of Miramichi Bay; as this is the point furthest removed from the deep-water and from the tidal entrance at Cabot Strait. The tide-gauge now on the Magdalen Islands will give, in a comparatively short time, a record sufficient to establish its tidal difference from St. Paul Island; and it can then be utilized for the more permanently important position at Miramichi. This change may therefore be made with advantage before the end of next season.

At Father Point the erection of the tide-gauge was not finished, up to the beginning of the present winter, when the ice stopped further operations. It is a position

which presents much difficulty, as the gauge has to be placed above high-water mark to prevent it from being carried away by the heavy ice which drifts up and down the river with the tide. This necessitates the excavation of a trench 280 feet in length across a foreshore of shale rock to lead the tide to the gauge. On account of these difficulties the wharf at Rimouski, some six miles distant, was examined before the work was commenced. The dredging of the silt to deepen the water at this wharf has caused it to settle, and there is no certainty that further settlement may not take place, which would interfere seriously with observations made by a gauge placed upon it. Also in winter, there is no one at the warf in the employ of the Government to carry on the observations; and the employment of a competent observer for the purpose would be less economical than to make the expenditure required to establish the gauge at Father Point. The practical advantage of Father Point as the Pilot Station, is a still more important argument in its favour. The erection of the gauge there should therefore be completed as soon as possible next season.

To complete the number of principal stations for the tidal observations in accordance with the explanations above given, three additional tides gauges should be erected at Yarmouth, Halifax, and Belle Isle respectively; the station at Father Point should be completed, and the tide gauge on the Magdalen Islands should be removed to the vicinity of Miramichi Bay. I would recommend that this be done during the coming season in order that the stations may be in operation at the earliest possible date.

CURRENTS.

There are two ways in which marine currents may be classified. From the point of view of the main routes of navigation which traverse the Gulf and follow our coasts, they may be termed Speed Currents or Cross Currents, according as they assist or retard a vessel, or tend to carry it laterally out of its course. The Gulf Stream off the American coast affords an example on a large scale of a speed current; as vessels between New York and the West Indies can obtain a distinct advantage in time by following or avoiding it. On the other hand with reference to the causes which give rise to the currents, a distinction may be made between tidal currents and those produced largely or wholly by the wind. In this connection also, the relation between surface currents and under currents is important; as the wind may displace a surface current from its normal position, and thus allow the water beneath to replace it to a greater or less extent. There are other causes also, such as difference of temperature, which may bring an under current to the surface, or occasion a surface current to sink. It must not, therefore, be hastily assumed that information regarding under currents is of no practical use for the purpose of navigation. In addition to these causes the height of the barometer may also have an appreciable effect on the movement of currents.

In illustration of the above points, some examples may be given from what is already more or less distinctly known or supposed to take place in the Lower St. Lawrence and Gulf; and these examples may also serve to show the nature of the information that it is so exceedingly important to obtain with at least some degree of certainty.

From Quebec to Father Point the tidal currents occupy the whole width of the River; and although they may class as speed currents, it is only the smaller sailing craft that take any advantage of them. The steamships take their chance of gain or loss and disregard them; although the direction of the current has to be considered in calculating time of arrival in port, and making railway connections. Where the River widens the case is different, as part of the width is occupied by a constant downward current which appears usually to run parallel to the south shore at no great distance from it, all the way to Gaspé. It is possible that this current may prove to be due in some measure to the warmer and fresher waters of the St. Lawrence river, which would naturally float to the surface; and its tendency to keep to the south side may be occasioned by the prevailing direction of the wind.

There is also some reason to suppose that with severe or long continued south-westerly winds, this current is displaced from its usual course and made to set in against the south side of Anticosti. If this supposition is correct, it would help to account for the "Caution" found on the chart in this neighbourhood to the effect that "the currents are governed principally by the wind." A knowledge of the usual course of such a current, and the reasons for its change in position, would enable this vague caution to be replaced by some much more definite statement, to show mariners what they have actually to expect. In the part of the Gulf to the eastward of the Magdalen Islands and Anticosti, there are some indications that the surface water has a movement in a north-westerly direction. If this movement is found to exist either permanently or at certain times, it will furnish an example of a cross current on the route of vessels coming inwards through Belle Isle. The tendency of such a current to set them to the northward of their course, would then help to explain why so many vessels in endeavouring to round the eastern end of Anticosti are wrecked on its north-eastern shores. The great importance of ascertaining the actual facts in such cases as these, is very evident.

There are other directions also in addition to the interests of shipping, in which a knowledge of the currents may be indirectly of practical importance. The good fishing grounds on the Atlantic coasts of Newfoundland and Nova Scotia and along New England are acknowledged to be due to the cold northern current which skirts these shores. It is generally believed that the cold water which enters at Belle Isle, floods the bottom of the Gulf in its deeper parts; and some knowledge of the extent to which this is the case, may throw light indirectly on the distribution of cold water fish in the Gulf area. On the other hand the oyster is found in the warmer waters of the Gulf, along the shores of New Brunswick and Prince Edward Island; although on the Atlantic coast it does not occur much north of Portland. The water is naturally warmest in the shallow parts which are least disturbed by currents; and the relation between the movement of the water and the temperature, may therefore have a bearing on the localities which the oyster prefers.

It is well known that the height of the barometer has an effect on the height of the tide. This is explained in general terms, by saying that the decreased pressure of the air allows the tide to rise higher than it otherwise would; as the difference in pressure of an inch of mercury corresponds to about a foot in the height of water. The amount of difference likely to occur in the actual height of the tide from this cause, is of little practical importance, except in the case of a harbour with a bar across its mouth. But the effect on the tidal currents may often be much more marked. For example, a low barometer over the Bay of Fundy with a rising tide can hardly fail to increase the velocity of the currents; and the amount of this increase ought to be determined. In land-locked areas such as the Gulf of St. Lawrence, the effect of the barometer is usually quite distinct, if we may judge by such similar instances as the Baltic Sea and the Gulf of Mexico. With a high barometer over the area of that gulf, and a lower pressure over the ocean outside, the speed of the Gulf Stream is appreciably affected. The conditions are closely parallel in the case of the Gulf of St. Lawrence, when the low pressure area of a storm is passing over the outer banks, on the course which these storms usually follow. If this is also accompanied by a strong north-westerly wind across the Gulf, it is to be expected that a considerable volume of water will be driven out at Cabot Strait, by these two causes acting together, and that the general equilibrium of the Gulf will be disturbed.

On account of these effects of the changes in atmospheric pressure, the readings of the barometer are always recorded in connection with tidal stations. This is being done in all cases in which there is no neighbouring meteorological station which will serve the purpose.

TIDES AND CURRENTS OF THE PACIFIC.

On the Pacific Coast the principal harbours of Victoria, New Westminster, Vancouver and Nanaimo, are all situated on the straits or interior waters within

Vancouver Island; and the tides and currents in these are very complicated in their character. As the Gulf of Georgia, which forms the largest of these interior waters, communicates with the Pacific both to the west and to the north, the tides enter from both these directions; and the tidal currents of the numerous sounds and inlets which open off the Gulf itself, are thus complicated with those of the entering tides. It will therefore be necessary to determine as a basis the tide in the open Pacific, where it is uninfluenced by the effects of the currents in the inlets. For this purpose the best point to select is probably Cape Beale on the west side of Vancouver Island. It is the most northerly lighthouse point on that shore, and furthest removed from the mouth of the strait of San Juan de Fuca; and the form of the Cape itself indicates a good shelter besides it.

In selecting a position at which to observe the general tide in the area of the Gulf of Georgia, it must be remembered that the object in view is chiefly to establish a standard to which the direction and time of change of the currents can be referred; just as the currents in the English channel are referred to the time of high water at Dover. For the straits and inlets of the Pacific Coast, the speed of the currents, their direction and time of change, are fully more important to a vessel than the actual time of high water at the harbour to which it may be bound. With this in view, the harbours of Vancouver and New Westminster which open off the Gulf, are not likely to prove suitable for the purpose; on account of the disturbing influences of Burrard Inlet and the Fraser River. The position chosen should be on the open shore of the Gulf, where it would be free from such influences, and also from the tide-rips which occur at the mouths of the smaller channels. A position at or near Nanaimo would fulfil these requirements, and would also be centrally situated with regard to the area of the Gulf. It is probable that this will prove on the whole the most suitable position for a tide-station, to which the currents throughout these straits can be referred. It will serve at the same time as a reference station from which the tides at Vancouver and New Westminster can be determined.

The harbour of Victoria occupies an intermediate position between the outside tides of the Pacific and those of the interior waters of the Gulf. It would be well, therefore, to have a tide station at Victoria or Esquimalt to command the Strait of Fuca, and to serve as a connecting link between the outside and inside tides as found at the other two stations, as well as for the sake of the harbour of Victoria itself.

The northern navigation to Alaska must remain for some time to come in the hands of captains who have had the opportunities to acquire a local acquaintance with the tides and currents on that route. But for the principal harbours of British Columbia the three positions I have indicated will serve as reference stations for the tides and currents on the main lines of navigation. The tide gauges at these points should be erected at the same time, to obtain the relation required between the observations.

In considering where additional tide gauges are first required and where the survey of the currents should be commenced, the relative needs in the interest of shipping should be kept in view. On the Pacific coast the currents themselves are on the whole stronger and more variable than those encountered by the same classes of vessels on our eastern shores. On the main lines of navigation, however, the pilots join the vessels at the entrance to the Strait of Fuca; and the vessels thus obtain the assistance of local knowledge from the outset, for the straits and inlets of that coast. In the Gulf of St. Lawrence, which is traversed on two different routes by trans-Atlantic vessels, the captains have to navigate its whole extent of some 600 miles after making land, before they reach the pilot station at Father Point. It is therefore advisable that the credit which may be made available for the purposes of this survey, should be laid out during the coming season in completing on our eastern shores the number of tide gauges required, and commencing the survey of the currents. If these are completed this season, a corresponding outlay in the season of next year, to that now estimated for the establishment of tide gauges, would equip the Pacific coast with the gauges required to obtain a basis of reference for both tides and currents.

SURVEY OF CURRENTS.

The information obtained by means of the survey should be classed and described as (1) normal conditions, and (2) exceptional conditions and disturbing influences. The normal conditions of the Gulf of St. Lawrence during the season of navigation, are a fairly steady barometer and prevailing wind from the south-west; and some of the exceptional conditions already described may be taken as examples of disturbing influences.

Under the normal conditions then, the leading causes which produce the currents are the tides themselves and the force of the prevailing wind. It is therefore necessary that the winds and tides should be observed throughout the time that the survey of the currents is in progress. In recording the winds Mr. Carpmeal will be glad to co-operate by equipping more fully any of the present observatories where this may be necessary. This survey will also afford another direction in which the numerous meteorological observations now taken, may be utilized for the practical advantage of seamen. When all the tidal stations which I have indicated are established, there will be five in the Gulf and Lower St. Lawrence without counting Quebec. These must be maintained while the survey of the current is being made, to furnish the tidal data required; and during that time it may also be possible to establish some of the tidal differences between the present stations with sufficient accuracy to enable one or more of the tide gauges to be removed and utilized at new positions. It is therefore most advantageous in the interests of the work as a whole, that the survey of the currents should be commenced at once. It will also prove more economical in the long run to do so; and there is the further practical advantage of obtaining as soon as possible information which is so much needed. I would therefore recommend that this branch of the work be commenced this season.

The records made by the tide gauges now in operation have already accumulated to some extent; and it is only at present that a beginning is being made in the direction of working up the results. With the commencement of the survey of the currents, the staff at work in the summer season, could be utilized in the winter months to work up the tidal observations of the whole year. This affords a further reason in favour of carrying on the two branches of the work together.

METHODS AND APPLIANCES.

With regard to methods and appliances, it will only be necessary at present to make a few general remarks. Marine surveys have received a great stimulus in recent years from the "Challenger" expedition fitted out by the British Admiralty and from the investigations of the Gulf Stream by the "Blake" in connection with the United States Coast Survey. Much progress has thus been made in the appliances used; the use of the drift buoy for the measurement of currents has been largely superseded by the current-meter, although in some cases the older methods can still be used to advantage. The appliances devised for the "Blake" have made it practicable to anchor in depths ranging from 2,000 to 3,000 fathoms. It is of the greatest advantage to work from a vessel at anchor, as it affords a fixed point from which to determine the direction and velocity of the currents. This is especially important where the land is too distant to determine the direction and speed of a current by the drift of the vessel itself; and such determinations from drifting are in any case complicated with lee-way from the wind. The depths in the Gulf are not so formidable as those encountered by the "Blake," as they nowhere exceed 300 fathoms. For the survey of currents the use of a sailing vessel is found to be impracticable on account of the long delay in arriving at the spot where the observations are required and the impossibility of doing so in a calm, which is the very time when the observations would be the most accurate, the long time required to heave up the anchor by a hand windlass, and the danger to the vessel during this delay, if bad weather is the cause of departure. For these reasons it is necessary to have a steamer with steam winches, &c., which a few additional appliances would prepare for anchoring.

The observations should include the density and the temperature of the water, as well as the direction of the currents. The density is chiefly useful as an indication of its admixture with fresh water, either in the estuary or in the neighbourhood of melting icebergs. The temperature has always been found a valuable guide in tracing currents. In some situations it will be advisable to determine the undercurrents also. The speed of the surface currents themselves, I propose to determine at a uniform depth of 10 feet, as this may be taken in general as half the average draught of a vessel. The speed, at this depth, will best show the movement of the body of the surface water, in relation to its effect in drifting a vessel.

In the coming season, I would recommend, as the most effective way to commence the work, that surveys be made of the two main entrances to the Gulf at Belle Isle, and at Cabot Strait between Cape Breton and Newfoundland, in order to determine the amount and direction of the currents that may be found to pass through these dominant openings. To do this work satisfactorily, observations should be carried on simultaneously at the two places, and should be continued for about three months, in order to secure the truly normal conditions of the currents, the effect of the difference between the spring and neap tides, and the disturbing effect of such exceptional conditions as may occur during that time. The under currents should be determined as well as the surface currents, so that the total amount of water which enters or leaves the Gulf area by these openings may be ascertained. The volume discharged by the St. Lawrence may also be taken into account, although a very slight movement of the waters at these large openings would more than make up for it. In this way some general basis will be obtained for the survey of the currents in the interior of the Gulf.

The sum required to carry out this work during the fiscal year 1894–1895 is shown in the estimate which I beg to append below; and I believe that to carry out the work as outlined and estimated in this report, is the most efficient and economical way of carrying on this Survey from the position it has already reached.

COMPLETION OF THE SURVEY.

The time required for the survey of the currents on both the Atlantic and Pacific coasts will be about six or eight years; on the basis of an annual expenditure as indicated, and the average annual cost should be fully covered by the amount of the present estimate; with the exception of the sum allowed for the use of the steamer, which in future years should be available for the full season. With this proviso, it will be possible in the time stated to survey the currents in the open waters traversed by the ocean-going vessels, and on the main routes leading to our principal harbours; but it does not contemplate an examination in detail of the currents in the less important bays and straits. The amount of the estimate also includes the additional tide gauges to be established in the first two seasons in advance of the survey of the currents in each region. The margin corresponding to this in later years can be used to carry forward the tidal work, until the completion of the survey of the currents; when the remaining tidal work can be completed satisfactorily on the basis of a much reduced expenditure.

SUMMARY.

The following summary may be given in conclusion, with special reference to the work for the coming season:—

1. The representations made in past years have shown the imperative need of obtaining full information as to the tides and currents in Canadian waters; and this is now generally admitted and recognized.

2. A practical commencement has been made by the erection of five tide gauges now in operation, and also by the publication of tide tables for the port of Halifax by this department.

3. It is now proposed to complete the series of tide gauges required in the Gulf, and on the Atlantic coast; and also to commence the Survey of the currents in the Gulf of St. Lawrence.

4. The credit of $10,000 voted by Parliament, was for the erection of tide gauges and the reduction of the tidal observations; and did not include provision for the Survey of the currents.

5. It may also be noted that out of the two annual credits of $10,000 each, made available up to June, 1893, little over one-fourth was actually expended on the work.

I have, sir, the honour to remain,
Your obedient servant,

W. BELL DAWSON,
Engineer in charge of Tidal Survey.

SURVEY OF TIDES AND CURRENTS.

Estimate for the Fiscal Year 1894–95.

Three new tidal stations at Belle Isle, Halifax, and Yarmouth, including cost of tide-gauges and erection....	$	3,500
Removal of tide-gauge from Magdalen Islands to Miramichi, after nine months..		900
Completion of gauge at Father Point		700
Maintenance of nine tidal stations, at $300 each, including salary of observers		2,700
Publication of tide tables		300
Engineer in charge, salary		2,000
Assistant to supervise erection of tide-gauges, and three assistant surveyors and computers, for survey of the currents, and for working up the tidal observations.		3,600
Travelling expenses and field expenses of staff		1,800
Hire of boatmen		900
Fittings for steamer, deep sea anchorage, sounding appliances, current meters, instruments, &c		2,500
Add for contingencies—say 5 per cent		1,100
	$	20,000
Use of steamer for four months at the rate of $15,000 for a full season of seven months		9,000
	$	29,000

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